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CDF Top Results in the Dilepton Channel

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ABSTRACT

The current status of the top quark search at CDF in the dilepton channel is presented. In the 1992-93 run (Run Ia), with 19.3 pb^{-1} collected, two $e\mu$ events survived all the cuts, including a two-jet cut for high mass top, with a total estimated background of $0.56^{+0.25}_{-0.13}$ events. With approximately 9 pb^{-1} of data analyzed from the 1993-94 run (Run Ib) a new $e\mu$ event passing all the cuts has been detected.

1. Top Quark Production and Decay at the Tevatron. The Dilepton Channel

The process $q\bar{q} \rightarrow t\bar{t}$ is the dominant one for top quark production at the Fermilab Tevatron (center of mass energy of 1.8 TeV). The cross section is a steeply falling function of the top quark mass varying from 30 pb at 120 GeV to 5 pb at 190 GeV. The top quark is expected to decay into a W boson and a b-quark assuming no deviations from the Standard Model. So, the produced top quark pairs have three possible decay channels, giving three different search methods:

1. The dilepton, electrons or muons (taus are not considered) and two jets (the b-quark jets) in the final state. This is the cleanest channel but has the lowest branching ratio (4/81).

2. The single electron or muon (taus are not considered) plus three or four jets (the b-quark jets and the two jets coming from the hadronic decay of a W) in the final state, having a branching ratio of 24/81.

3. The six jets final state, having a branching ratio of 36/81.

In this contribution we report on the results from the dilepton channel search mainly from the 19.3 ± 0.7 pb^{-1} collected by CDF during the 1992-93 run (Run Ia).

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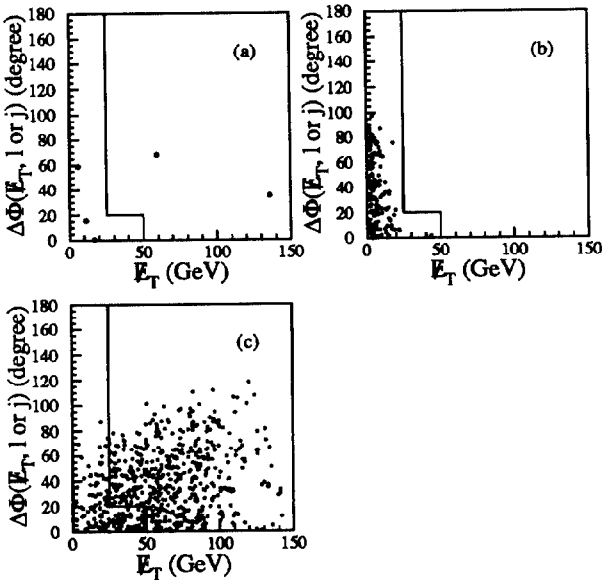

Fig. 1. Distributions of the azimuthal angle between missing E_T and the closest lepton or jet versus E_T. a) $e\mu$ data. b) Dielectron and dimuon data after the invariant mass cut. c) Monte Carlo (unnormalized) events for $M_{top} = 160\ GeV/c^2$.

2. Dilepton Event Selection

Two high p_T ($P_T > 20\ GeV$) leptons (electrons or muons) with opposite charges are required in this channel. At least one lepton has to be central ($|\eta| < 1.0$) and pass tight identification requirements and a track isolation cut (with an efficiency of $87 \pm 1\%$). The second lepton may pass looser cuts (with an efficiency of $94 \pm 1\%$).

An invariant mass cut is applied to remove $Z's$ in ee, $\mu\mu$: $75\ GeV/c^2 < M_{ll} < 105\ GeV/c^2$. For $M_{top} = 160\ GeV/c^2$, 80 % of dielectron and dimuon events pass the invariant mass cut.

Due to the presence of two high P_T neutrinos in the top dilepton channel a missing E_T cut is applied on its magnitude: $\not\!\!E_T > 25\ GeV$. At this point, the background is dominated by Drell-Yan in the ee, $\mu\mu$ channels and by $Z \rightarrow \tau\tau$ in the $e\mu$ channel. For events with $\not\!\!E_T < 50 GeV$ it is also required that the azimuthal angle between the $\not\!\!E_T$ direction and the direction of the closest jet be $\Delta\phi(\not\!\!E_T, jet) > 20^0$ to reject the Drell-Yan continuum background, which would pass the missing $\not\!\!E_T$ magnitude cut due to mis-measured jet energies from cracks, etc. A similar cut is applied to the direction of $\not\!\!E_T$ with respect to leptons to reject the $Z \rightarrow \tau\tau$ background ($\Delta\phi(\not\!\!E_T, l) > 20^0$ when $\not\!\!E_T < 50\ GeV/c^2$), since the missing $\not\!\!E_T$ produced by neutrinos from $\tau's$ goes primarily along the lepton direction. For $M_{top} = 160\ GeV/c^2$, 76 % of the dilepton events pass all the missing $\not\!\!E_T$ cuts.

After all these cuts, there are two $e\mu$ events (see figure 1) and no dielectron nor dimuon events in the signal region.

For a high mass top ($M_{top} > 120\ GeV/c^2$) the two b-quarks will form high E_T jets with high efficiency. So, we require two or more jets with tranverse energy greater than 10 GeV. The two-jet cut reduces the background by a factor 4 while being 84 % efficient for $M_{top} = 160\ GeV/c^2$. The remaining two events also pass the two-jet cut.

The number of data events surviving the sequence of cuts is shown in table 1.

Cut	$e\mu$	ee	$\mu\mu$
P_T	8	702	588
Opposite-Charge	6	695	583
Isolation	5	685	571
Invariant Mass	5	58	62
$\not\!\!E_T$ magnitude	2	0	1
$\not\!\!E_T$ direction	2	0	0
Two-jet	2	0	0

Table 1. Number of data events surviving consecutive requirements.

3. Dilepton Acceptance

The efficiency has been studied mainly with the Isajet Monte Carlo program[1]. The detection efficiencies, the predicted central value of the $t\bar{t}$ production cross section from the NNLO theoretical cross section[2] and the number of expected events in $19.3 pb^{-1}$ is given in table 2. After all the cuts, the contribution from the different channels is: $e\mu$: 59%; ee : 21%; $\mu\mu$: 20%.

M_{top} GeV/c^2	ϵ_{DIL}	$\sigma_{t\bar{t}}$ pb	$N_{e\mu}$ events	$N_{e\mu,ee,\mu\mu}$ events
120	0.0049	38.9	2.2	3.7
140	0.0066	16.9	1.3	2.2
160	0.0078	8.2	0.8	1.3
180	0.0086	4.2	0.4	0.7

Table 2. Detection efficiencies, $\epsilon_{DIL} = Br \cdot \epsilon_{total}$, the predicted central value of $t\bar{t}$ production cross section and the number of events expected in 19.3 pb^{-1}, as functions of top mass.

The dilepton acceptance uncertainty is dominated by the two-jet cut which varies from 36% to 3% (M_{top} 100 $-$ 180 GeV/c^2). The other cuts have uncertainties which do not depend strongly on the value of the top mass.

4. Dilepton Backgrounds

The most important backgrounds have been estimated to be WW, Drell-Yan ($\gamma/Z \rightarrow ee$, $\mu\mu$), $Z \rightarrow \tau\tau$, $b\bar{b}$ processes and QCD or W+jets processes with at least one misidentified lepton.

The WW background is estimated using the Isajet Monte Carlo program, normalized to a total cross section of 9.5 pb, and the CDF detector simulation. Before the two-jet cut we expect 1.17 ± 0.37 events, where the error is dominated by the theoretical uncertainty in the cross section. Only 13% of the events pass the two-jet cut. The effects of initial state radiation for the two-jet cut are checked using the Drell-Yan process. The total WW background after the two-jet cut is predicted to be 0.16 ± 0.06 events.

The $\tau\tau$ background is determined using the hybrid technique of taking the $Z \rightarrow ee$ events and substituting Monte Carlo generated taus in place of the electrons. We expect 0.13 ± 0.04 events after the two-jet cut.

The $b\bar{b}$ background is estimated using the Isajet Monte Carlo for the production and the CLEO Monte Carlo[3] for b decays. To check Isajet, the lepton P_T cut is lowered to 15 GeV/c and 5 GeV/c (for the first and second lepton, respectively), where heavy flavor is dominant, and the distributions found to be in good agreement with the $e\mu$ data. We predict 0.10 ± 0.06 events from this background.

The lepton misidentification background (QCD or W+jets processes with at least one fake lepton) is determined using jet data samples to assign a probability per track to pass the electron and muon identification cuts. These fake probabilities are applied to events with a good lepton plus additional tracks to estimate a total background of 0.07 ± 0.05 events.

The non-resonant Drell-Yan backgrounds for ee, $\mu\mu$ are determined using Z data to get scale factors for cuts (0.1% of Z events pass all the cuts, based on one $Z \rightarrow \mu\mu$ event), and apply the same scale factors to the number of non-resonant ee $\mu\mu$ events. We expect $0.10^{+0.23}_{-0.08}$ events from this background.

The total expected background is 0.24 ± 0.06 events in the $e\mu$ channel and $0.31^{+0.24}_{-0.10}$ in the ee, $\mu\mu$ channels. As a cross check of the background estimation in the $e\mu$ channel the lepton P_T is lowered to 15 GeV and the number of predicted events (25 ± 3) is found to be in good agreement with the number of events observed (18).

5. Conclusions

There are two events passing all the top selection cuts in the $e\mu$ channel from Run Ia ($19.3 \pm pb^{-1}$), while 3.7 (0.7) events are expected for $M_{top} = 120$ (180) GeV/c^2. The total expected background is $0.56^{+0.25}_{-0.13}$. One of the two top candidate events has a jet that has been b-tagged by both the SVX detector and the soft muon tagging algorithms. From the analysis of the new data from Run Ib ($\approx 9\ pb^{-1}$) one more $e\mu$ event has appeared passing all cuts.

References

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